Teach for 10-15 minutes at the start of the lab and cover the following subjects:

A. Current.

1. In class the concept of current might not have been introduced yet. The current has the units of ampere, or better Coulomb/second. So if a current is going through a wire or through a device, charge is moved from one side of the wire to the other side of the wire. When a circuit is connected to a battery, charge is transported from one pole of the battery through the circuit to the other pole of the battery.
2. The sign of the current is defined as follows: when connecting a circuit to a battery, a positive current flows from the positive pole of the battery through the circuit to the negative pole of a battery. So you can consider the battery to be a pump of charge. So compare a battery to the water pumps in Schlitterbahn. The pumps pump the water from a low potential energy to a high potential energy, and then once the water is released at the top, it flows down the slide. For each stage it will lower its potential energy with a certain amount. Similarly a battery can be considered to be a pump of positive charges, it pumps positive charges from a low potential energy (the negative pole of the battery) to the positive pole of the battery. Note that we learned in chapter in chapter 24 that the potential energy is given by:

$$U = qV$$

So the potential energy of the positive charges is much higher on the positive side of the battery as the electric potential is higher on that side. Once the positive charges are released at the positive side of the battery they flow through the circuit to the negative pole of the battery. For each device they pass through, their potential energy is lowered [1].

In class we learned however that in most materials charged is not moved around by the flow of positive charges. In metals for example only the negative electrons are able to move freely through the wire. So instead of having positive charges move from the positive pole of the battery through the circuit, to the negative pole of the battery, negative charges are moving from the negative pole of the battery through the circuit to the positive pole of the battery. Our picture of the battery being a pump for charge is still valid. The battery pumps negative charges from a low potential energy at its positive terminal to a high potential energy at its negative terminal. Note that because electrons have a negative charge, its potential is higher for locations where the electric potential is lower (read the negative pole of the battery). **Note that the sign convention of current is as follows: From the positive pole of the battery through the circuit to the negative pole of the battery (emphasize this).**

3. You can mention this but do not emphasize it: There are exceptions to this rule. In certain semiconductor materials, moving positive charges facilitate charge transport. These semiconductor materials are called p-type and are used in computer chips, transistors, and diodes. Those of your students in Electrical Engineering and Physics will learn more about those type of materials in junior and senior classes. Also in electrochemical systems, the move of charge can happen by the motion of positive charge, in this case positive ions.

4. As current is the transport of charge, a large current can be realized by (1) a large speed of the charges in the wire (we called this the drift velocity); (2) using a material that has large charge packages we call those charge carriers. Note that in a metal the charge package is simply the charge of a single electron, as electrons facilitate the transport of charge ; (3) using a material with a large number of free charges in the wire.

   Those three effects can be expressed in an equation:

   $I \sim n * e * v_d$

   Compare this with moving from one apartment to another apartment. You can move fast if you have a lot of pickup trucks, have large pickup trucks, and if you drive fast. Similarly you can move a lot of charge through a circuit, if your wires have a lot of free electrons, if your electrons move fast, and if each electron contains a lot of charge. The charge amount of each electron is fixed and equal to 1.6E-19 Coulomb. The number of free electrons in a wire depends on the material and is larger for copper than for for example glass.

B. Resistance

The speed of the electrons in the wires depends on the material of the wire but also on the electric force felt by the electrons. Note this is very similar to our moving story. The speed of the trucks depends on (1) the number of speed bumps and (2) how far the pedal is pushed towards the metal. For our circuit the electric force can be considered to be proportional to the voltage drop across the devices and across the wires. So the larger the voltage applied across a device or a circuit, the larger the electric field in the material. Note that we learned last week that:

$$E = \frac{V}{d}$$

Note that the force the free charges feel is proportional to the electric field, i.e.

$$F = qE$$

This force will accelerate the charges, so charges will move faster and faster until they ……. Collide with imperfections in the wire. Once the collide they will transfer their kinetic energy to the atoms creating heat and start again at zero velocity. So although the charges feel a constant force their speed will vary. We can determine an average speed, and that is called the drift velocity. This average speed depends on the number of collisions per second which depends on the type of material. The larger the V, the larger the E, the larger the F, the larger the drift velocity, the larger the current. For most materials the current is proportional to the voltage, i.e.

$$V / I = \mathrm{R}$$

The constant is referred to as resistance and identified with the symbol R. The larger the resistance the more difficult it is to get a current through the wire. The resistance has the units of volt per ampere, or Ohms.

Question: What kind of graph would one get if one plots the electric potential across a resistor versus the electric current going through the resistor?

The resistance of a wire can be calculated from its electrical properties and from the geometry of the wire. In class we will learn the following equation:

$$R = \rho \frac{L}{A}$$

Where ρ is the resistivity of the material and tells us how free electrons are in the material, and how easily free electrons move through the material (read the number of speed bumps). L is the length of the wire, and A is the cross section of the wire. So L and A are geometrical quantities.

Question: One can make a large resistance by or choosing a material with a large resistivity or choosing the geometry so R is large. How would you realize a large resistor, by making it long, or by making it have a large cross sectional area?

Also here an analogy with water is in place. Think of a water hose, or think of a straw in your favorite drink. The longer and the thinner the straw the more difficult it is to get a large flow of pop through it.

C. Parallel and Series equivalent resistance.

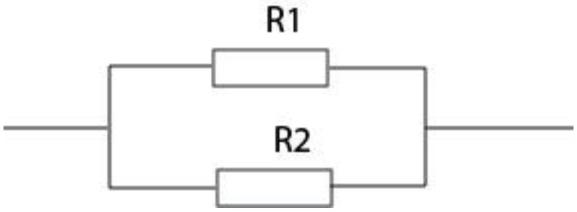
Question: We could place two resistors in series, i.e.

And determine the total resistance. If both resistors have the same value do you expect the equivalent resistance to be larger or smaller than the value of one of the resistors (only for non-EE students to answer).

Now discuss:

$$R_{total} = R_1 + R_2$$

Question: We could place two resistors in parallel, i.e.



and determine the total resistance. If both resistors have the same value do you expect the equivalent resistance to be larger or smaller than the value of one of the resistors (only for non-EE students to answer).

Now discuss:

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2}$$